

# REPORT DOCUMENTATION PAGE

Form Approved  
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**

1. REPORT DATE (DD-MM-YYYY)

2. REPORT TYPE  
Technical Papers

3. DATES COVERED (From - To)

4. TITLE AND SUBTITLE

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER  
1011

5e. TASK NUMBER  
CA9F

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Air Force Research Laboratory (AFMC)  
AFRL/PRS  
5 Pollux Drive  
Edwards AFB CA 93524-7048

8. PERFORMING ORGANIZATION  
REPORT

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Air Force Research Laboratory (AFMC)  
AFRL/PRS  
5 Pollux Drive  
Edwards AFB CA 93524-7048

10. SPONSOR/MONITOR'S  
ACRONYM(S)

11. SPONSOR/MONITOR'S  
NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

20030110 137

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:

17. LIMITATION  
OF ABSTRACT

18. NUMBER  
OF PAGES

19a. NAME OF RESPONSIBLE  
PERSON

a. REPORT

b. ABSTRACT

c. THIS PAGE

Unclassified

Unclassified

Unclassified

A

Leilani Richardson

19b. TELEPHONE NUMBER

(include area code)  
(661) 275-5015

Standard Form 298 (Rev. 8-98)  
Prescribed by ANSI Std. Z39.18

18 separate items enclosed

TP-1998-104

1011CH qf

MEMORANDUM FOR PRS (Contractor Publication)

FROM: PROI (TI) (STINFO)

18 May 1998

SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-TP-1998-104**  
Tim Miller (SPARTA) "Modeling of Interfacial Fracture in Photoelastic Specimens"

**Vugraphs**

(Statement A)



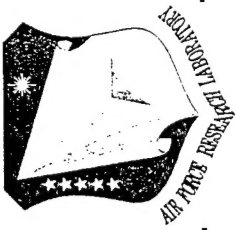
# Modeling of Interfacial Fracture in Photoelastic Specimens

T.C. Miller

Sparta, Incorporated  
Air Force Research Laboratory  
Edwards Air Force Base, California

**DISTRIBUTION STATEMENT A**  
Approved for Public Release  
Distribution Unlimited

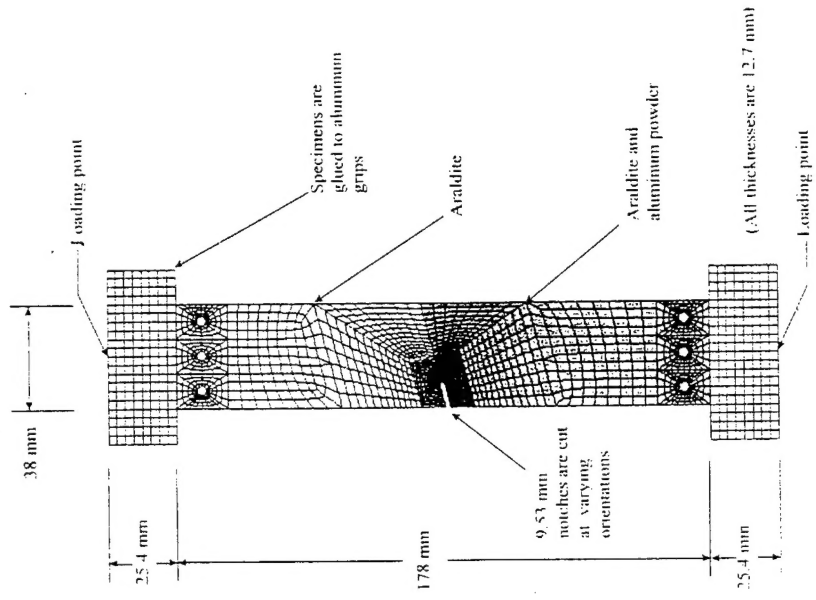
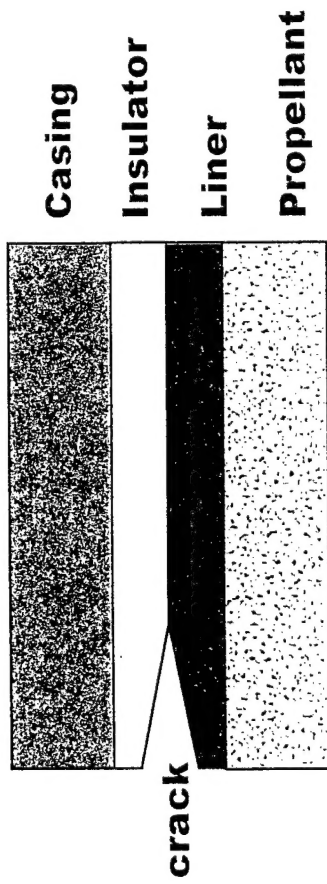
June 1998



# Introduction

## Applications to Composite Structures

## Related Photoelastic Stress Freezing Experiments





# Incompressible Bimaterial Paris Under Plane Strain Conditions

## General Interfacial Fracture

## Plane Strain/Incompressible Materials

$$\epsilon \neq 0 \quad \beta \neq 0$$

$$\sigma_{pq} = \frac{1}{\sqrt{2\pi r}} \{ \text{Re}(K r^{i\epsilon}) \Sigma_{pq}^I(\theta) + \text{Im}(K r^{i\epsilon}) \Sigma_{pq}^{II}(\theta) \}$$

$$(\sigma_{yy} + i\sigma_{xy})_{\theta=0} = \frac{K r^{i\epsilon}}{\sqrt{2\pi r}} = \frac{K_1 + iK_2}{\sqrt{2\pi r}} [\cos(\epsilon Lnr) + i \sin(\epsilon Lnr)]$$

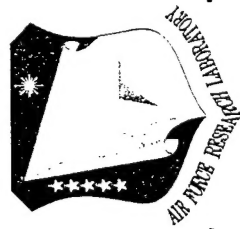
$$J = G = \frac{\Lambda_1 + \Lambda_2}{16 \cosh^2(\pi\epsilon)} |K|^2$$

$$\epsilon = 0 \quad \beta = 0$$

$$\sigma_{pq} = \frac{1}{\sqrt{2\pi r}} \{ \text{Re}(K) \Sigma_{pq}^I(\theta) + \text{Im}(K) \Sigma_{pq}^{II}(\theta) \}$$

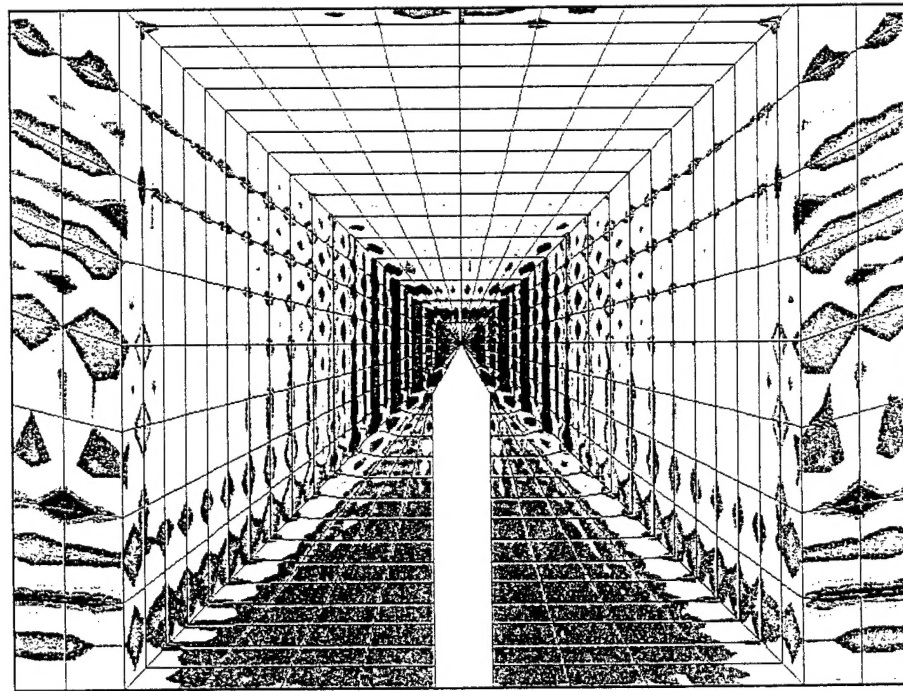
$$(\sigma_{yy} + i\sigma_{xy})_{\theta=0} = \frac{K}{\sqrt{2\pi r}} = \frac{K_1 + iK_2}{\sqrt{2\pi r}}$$

$$J = G = \frac{K^2}{E^*}, \quad \frac{1}{E^*} = \frac{1}{2} \left[ \frac{1}{E_1} + \frac{1}{E_2} \right], \quad \bar{E}_1 = \frac{E_1}{1 - \nu_1^2}, \quad \bar{E}_2 = \frac{E_2}{1 - \nu_2^2}$$

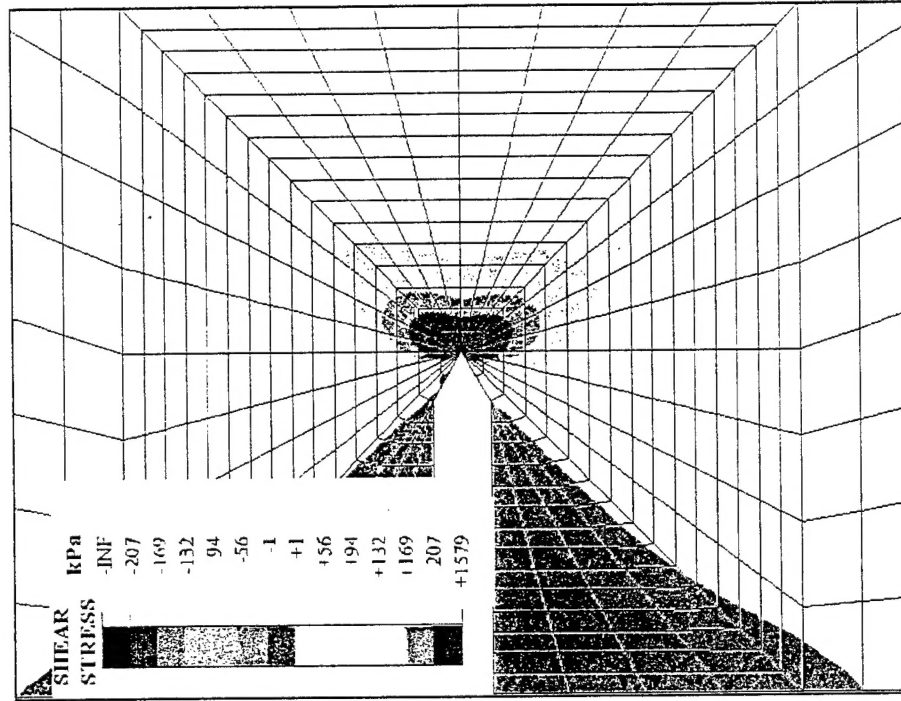


# Hybrid Elements and Mixed Formulation Prevent Ill-Conditioning Problems

Conventional Formulation

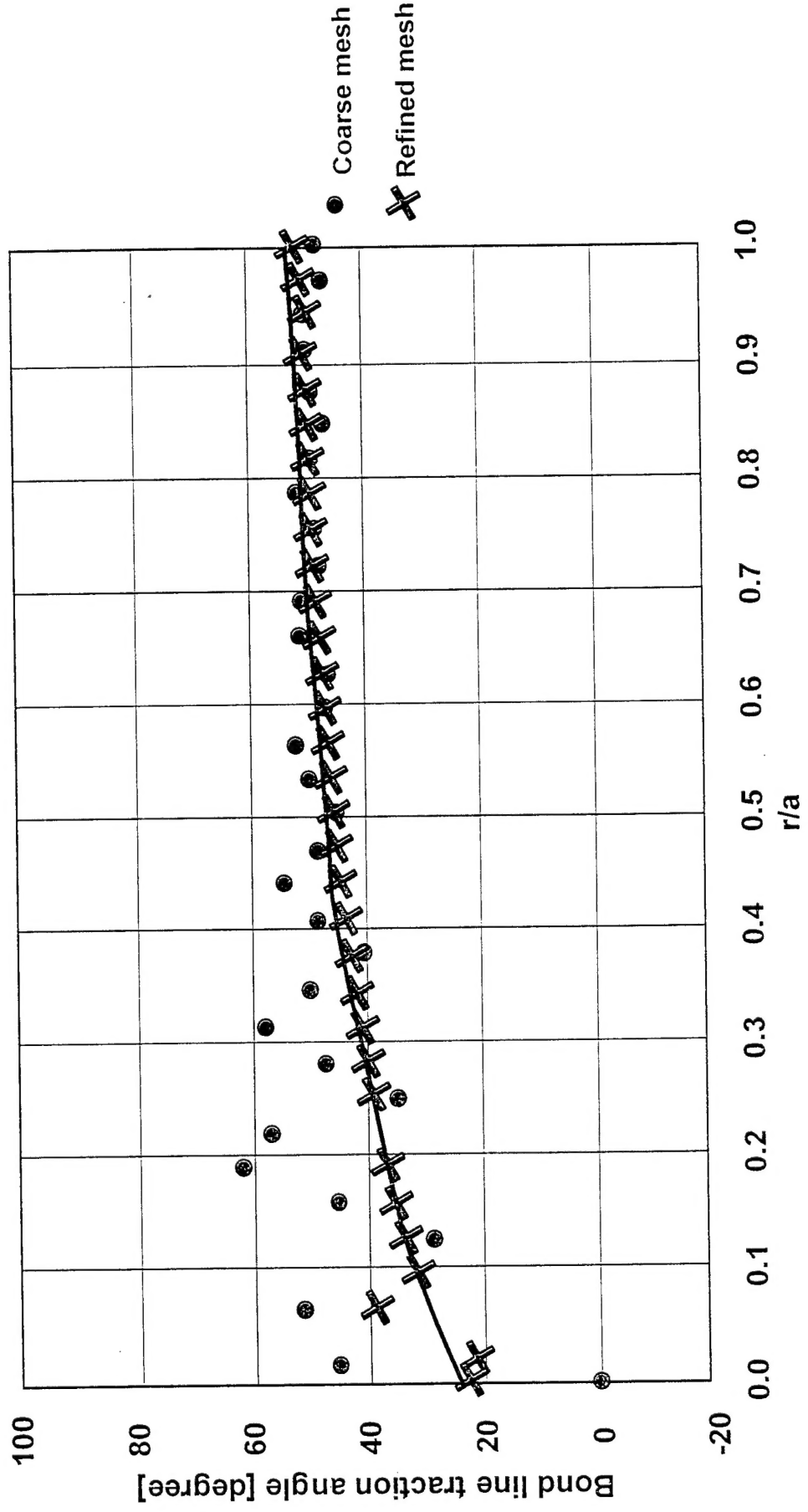


Mixed Formulation

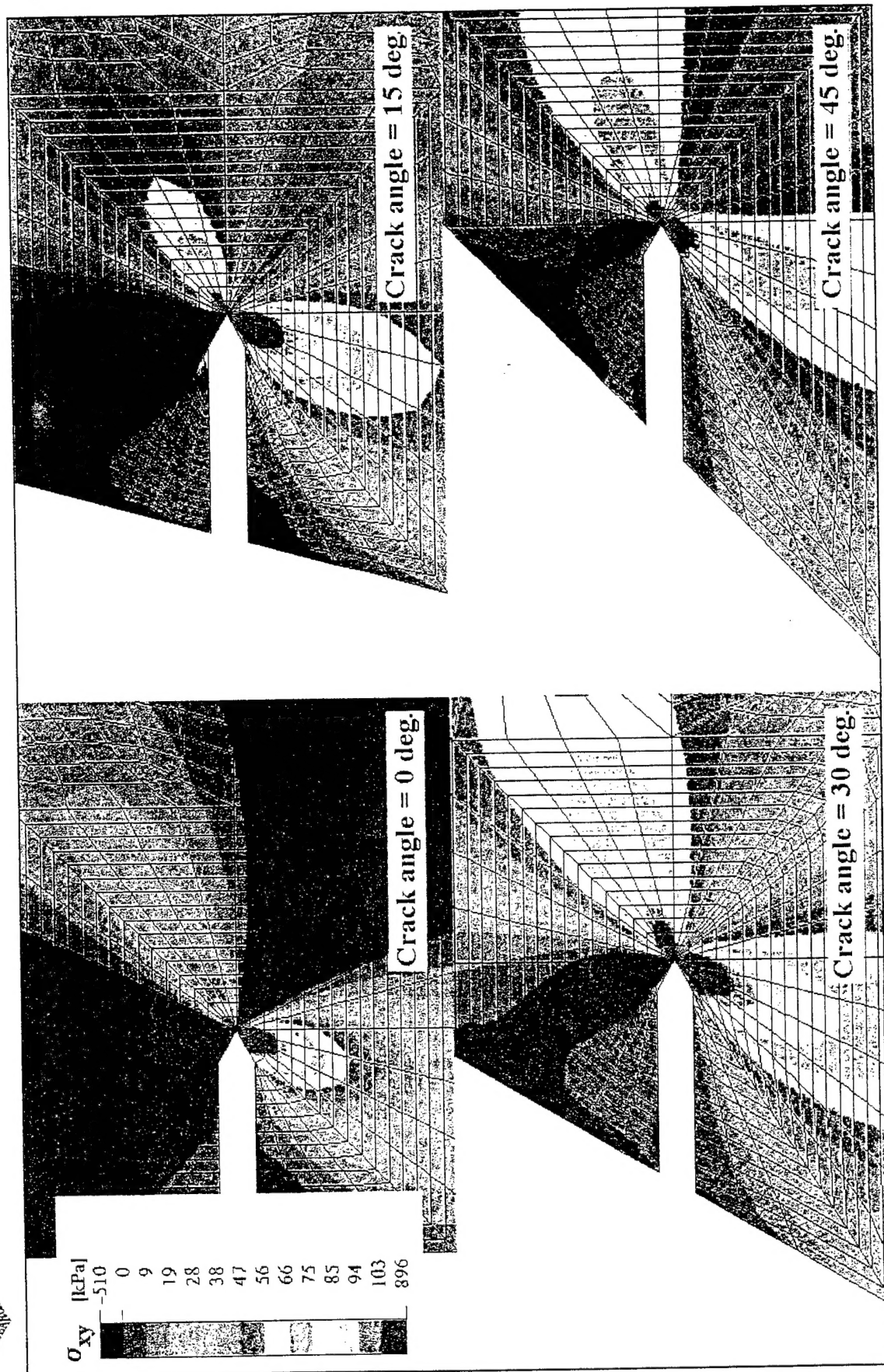




# A Refined Mesh is Used to Provide Accurate Bond Line Traction



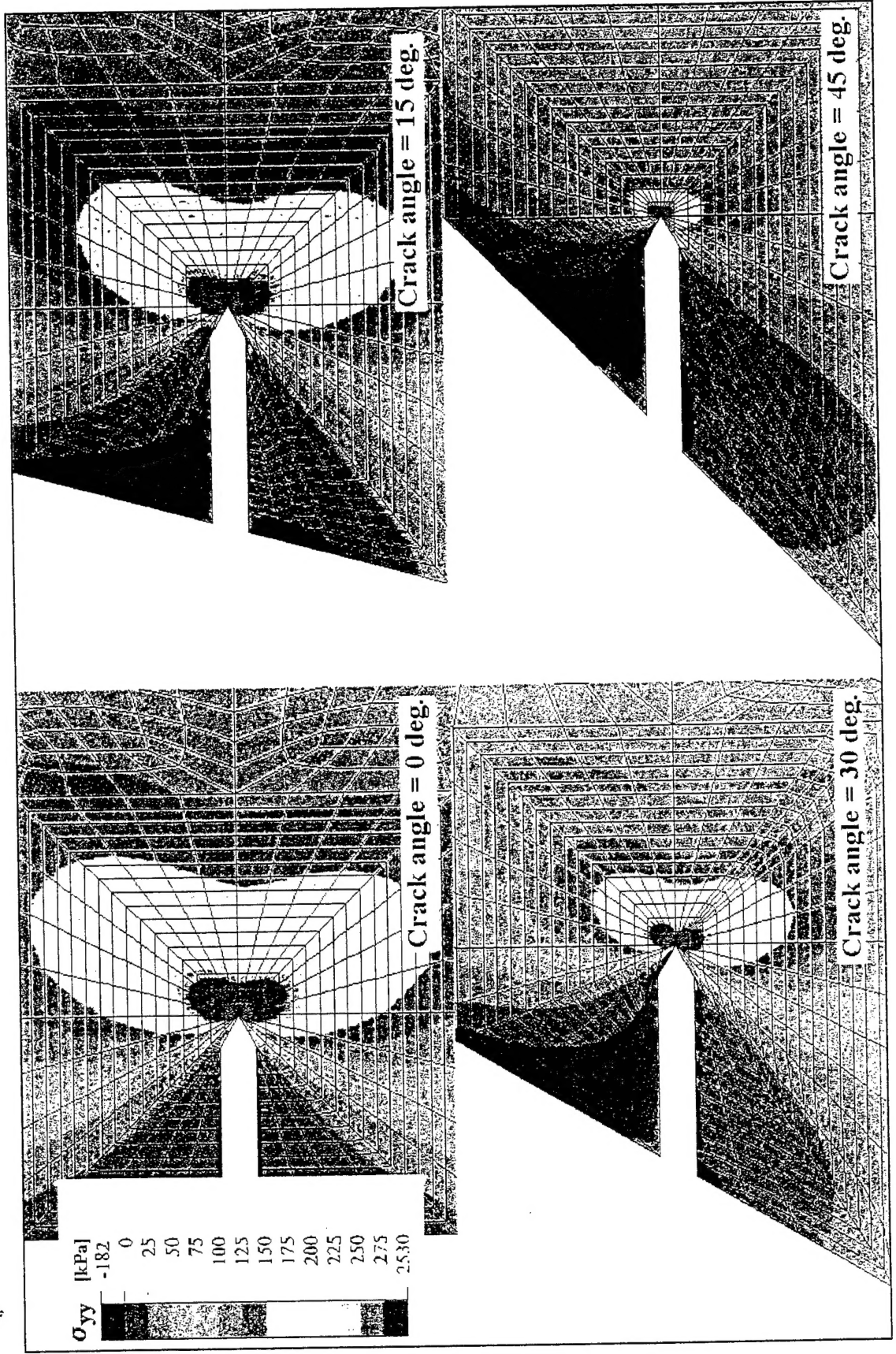
# Contour Plots of In-Plane Shear Stress for Various Mode Mixities



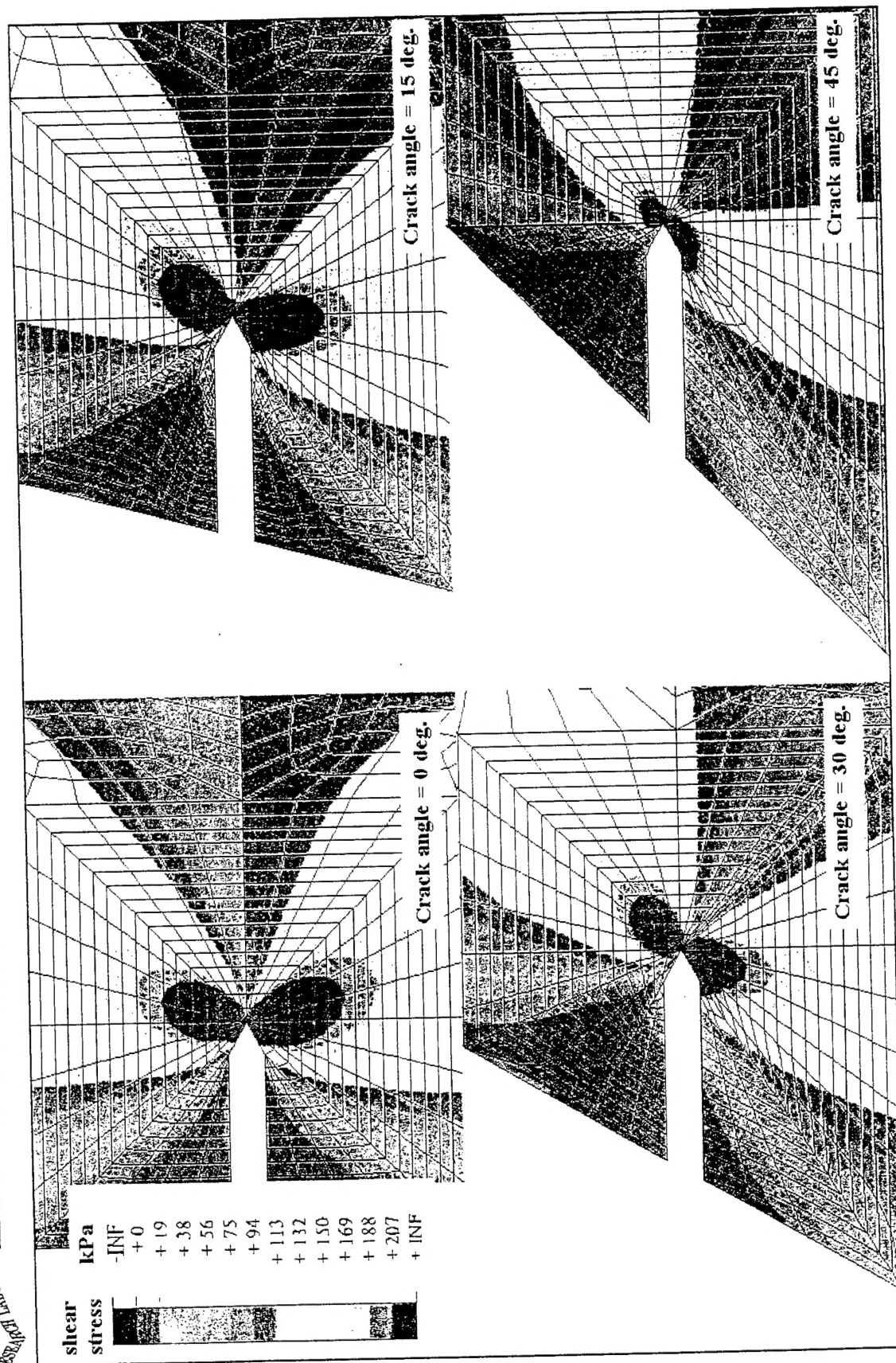




# Contour Plots of $\sigma_{yy}$ Stress Component for Various Mode Mixities



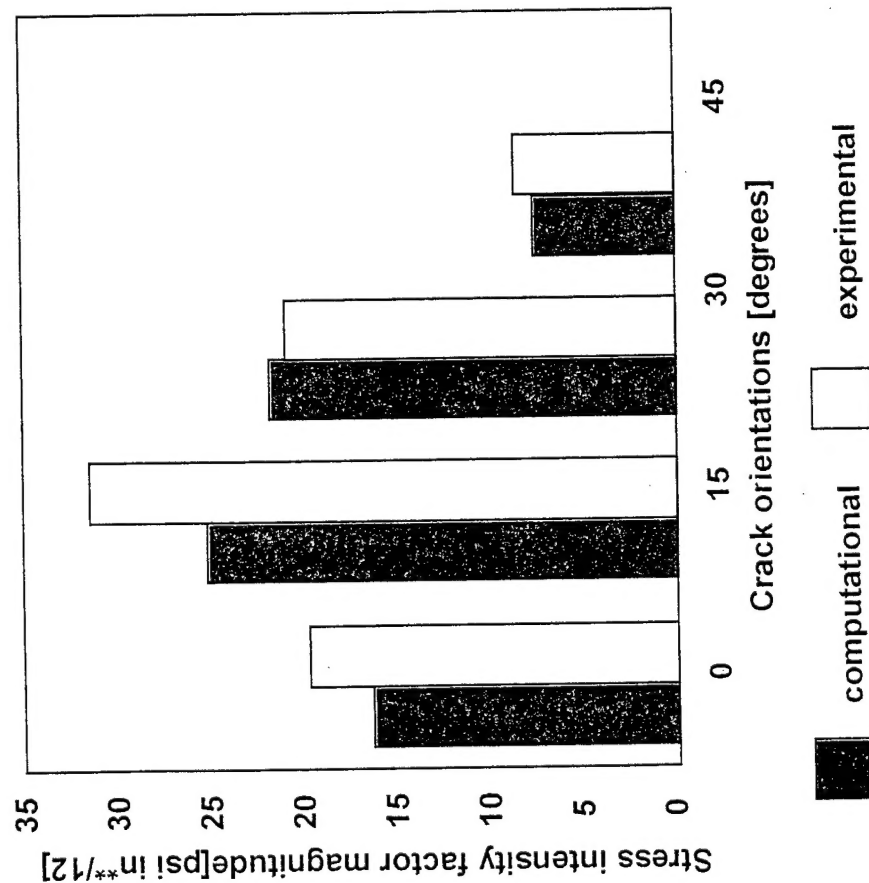
# Contour Plot of Maximum In-Plane Shear Stress Component for Various Mode Mixities



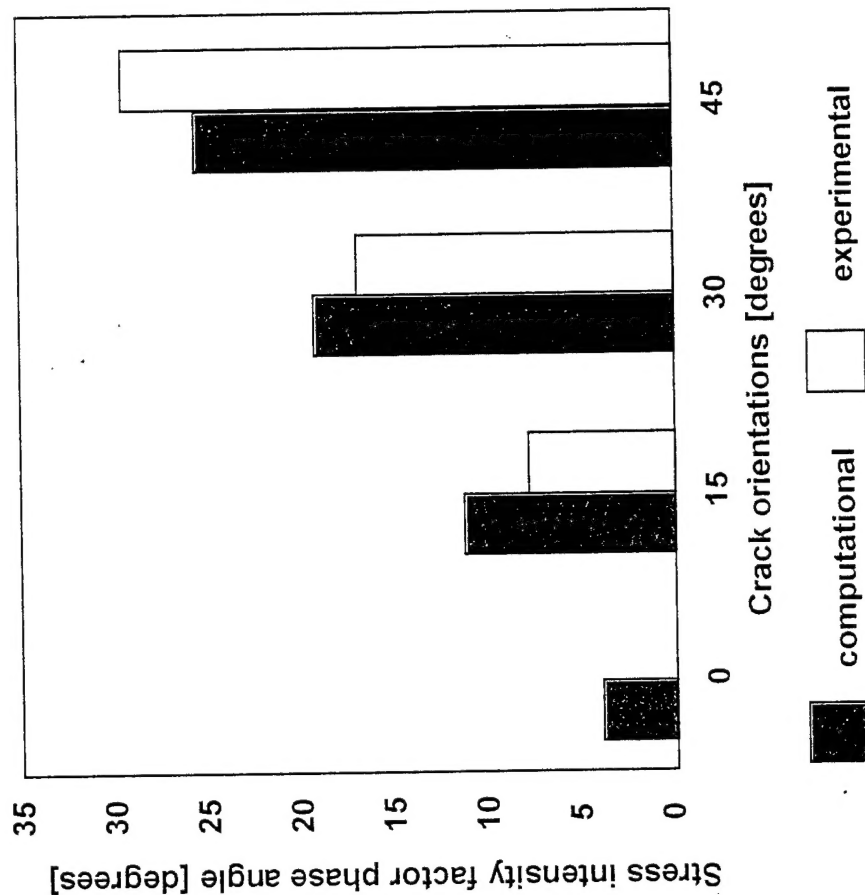


# Results

## Magnitude of Complex Stress Intensity Factors



## Phase Angle of Complex Stress Intensity Factors





# Conclusions

---

- Area integration and bond line traction regression is a simple and accurate way of determining the magnitude and phase angle of  $K$  for cracks along the interfaces between two incompressible materials under plane strain conditions.



# Acknowledgements

---

- Experimental results and data - Dr. C.W. Smith,  
Virginia Polytechnic Institute and State University
- Funding and Computational Facilities - Dr. C.T. Liu,  
Air Force Research Laboratory, Edwards Air Force  
Base, California